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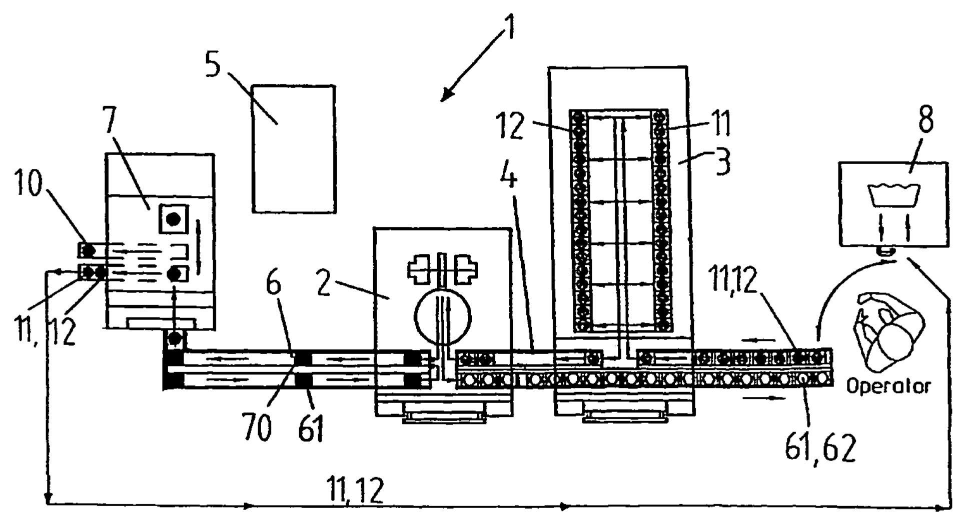

(57) Abstract: Described is a production line (1) for the production of ophthalmic lenses (10) that comprises a molding apparatus (2), at least one molding-shell-storage (3), at least one molding-shell-transporting-means (4), at least one operating unit (5), and preferably also a demolding apparatus (7) and molding-shell washing means (8). Said molding apparatus (8) and said demolding apparatus (7) are both suitable for fully automatized molding and demolding of ophthalmic lenses (10) and lens treatments such as coloring, hard coating and anti-reflective coating of lenses (10).

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Lens Production Line

Cross References to Related Applications

This application claims the priority of PCT application IB 01/00746, filed May 2, 2001, and PCT application IB01/00747, filed May 3, 2001,the disclosure of which is incorporated herein by reference in its entirety.

Technical Field

The present invention concerns a production line for the production of optical, in particular ophthalmic lenses.

Background Art

Hitherto ophthalmic lenses are usually produced by fine machining of optical blanks. In recent times, attempts have been made to directly mold ophthalmic lenses (see PCT/IB99/01776 = WO 01/32407) the disclosure of which is enclosed herein in its entirety by reference.

Many of the state of the art methods preferably use sealing means which cannot be reused because they must be either destroyed for disassembling or are getting soiled during polymerisation such that they would have to be cleaned if not disposable.

In US 6,103,148 an at least partially automatized system is disclosed. However, this system needs a complicated assembly station where front molding shell, rear molding shell and gasket are assembled and which is movably located outside the filling station that is also separate from the curing station. Thus, the lens forming method involving this apparatus necessitates that after

the filling step the filled mold is removed from the filling station and delivered to the curing station such that during each lens forming process, the whole assembly is removed and replaced by a new assembly.

Disconnecting the gasket from a liquid lens forming material conveying unit by which it has been filled, in particular prior to the lens having been cured, bears the risk that lens forming material soils the mold and/or the lens forming apparatus necessitating the undesired cleaning procedures already addressed above.

Therefore, all hitherto known ophthalmic lens production methods involve a lot of work performed by persons and/or complicated and numerous assembling and transporting devices.

Brief Description of the Invention

Hence, it is a general object of the invention to provide an at least partially automatized device or rather production line for the production of optical, in particular ophthalmic lenses that needs less manual work and/or a reduced number of devices, in particular a production line that integrates the assembling device with the lens forming device.

Now, in order to implement these and still further objects of the invention, which will become more readily apparent as the description proceeds, the production line for the production of optical, in particular ophthalmic lenses is manifested by the features that it comprises a molding apparatus, at least one molding-shell-storage, at least one molding-shell-transporting-means, and at least one operating unit, wherein

- said molding apparatus comprises a sealing means defining an essentially circular aperture around an axis, preferably an axis through the center of said sealing means, a liquid lens forming material conveying unit

to fill a molding cavity formed by a front molding shell and a back molding shell and the sealing means,

- said at least one molding-shell-storage comprises the molding shells in a manner suitable to allow easy access to a specific molding shell by the molding-shell-transporting-means,

- said at least one molding-shell-transporting-means being able to fetch molding shells from the molding-shell-storage and to position said molding shell in or on said sealing means,

- said at least one operating unit being such that it guides the molding-shell-transporting-means to fetch and position the back molding shell and/or the front molding shell in or on said sealing means, such that together with the sealing means they form a molding cavity, and wherein, preferably,

- said molding apparatus is constructed such that it allows to perform the following steps at the same location, namely to (i) assembly said gasket and said front molding shell and said back molding shell to form said molding cavity, and (ii) to fill said molding cavity, and (iii) to at least partially cure said filled molding cavity, and (iv) to remove said sealing means, such that the assembling and the filling of the molding cavity, the curing of the filled molding cavity, and the transport of an assembly consisting of an at least partially cured lens and said two molding shells outside of the molding apparatus is done without delocalization of the sealing means.

Further aspects, embodiments and advantages of the invention become apparent from the dependent claims in connection with the specification and drawings.

Brief Description of the Drawings

The invention will be better understood and objects other than those set forth above will become ap-

parent when consideration is given to the following detailed description thereof. Such description makes reference to the annexed drawings, wherein:

Figure 1 is a presentation of a production line fully automatized including the demolding step and with manual steps involved in washing of molding shells.

Figure 2A shows a schematic cross-sectional view of a preferred molding device suitable for the automatized production of ophthalmic lenses. The mold is shown in a disassembled state with a one-piece gasket having an aperture which is large enough in an opened state to receive the back molding shell due to a suitable gasket shape or to a radial gasket expansion;

Figure 2B shows a schematic cross-sectional view of a mold similar to Figure 2A but with a divisible gasket in a disassembled state.

Figure 2C shows a schematic cross-sectional view of the mold of Figure 2A and Figure 2B in a partially assembled state with the gasket already pressed to one of the molding shells,

Figure 2D shows a schematic cross-sectional view of the same molds as in Figures 2A to 2C in a fully assembled state.

Figure 3 shows a top view of a demolding apparatus with actively applied force from one side.

Figure 4 is a schematic cross-sectional view through part of the demolding apparatus showing the assembly with active force applied from two sides by means suitable for simultaneous force application to the front molding shell and the lens.

Figure 5 shows a schematic cross-sectional view through the force applying means of Figure 4 including a projecting finger for pressing onto and/or penetrating into the molded lens.

Figure 6a and Figure 6b show perspective views of a tray for a front molding shell or mold assem-

bly and for a back molding shell for their safeguarded handling and transportation in the production line.

Figure 7 shows a UV-polymerization of an ophthalmic lens using a transversely shaped intensity distribution.

Disclosure of preferred embodiments

The production line 1 of the present invention comprises at least one molding apparatus 2, at least one molding-shell-storage 3, at least one molding-shell-transporting-means 4, and at least one operating unit 5. Optionally said production line 1 can further comprise one or more of the following tools in the mentioned sequence: at least one assembly-transporting-means 6, at least one demolding apparatus 7, preferably integrated in the molding apparatus 2, and at least one molding shell 11, 12 washing apparatus 8 (see Figure 1). In addition, apparatuses for further treatment of lenses 10, such as tinting and/or hard coating and/or anti-reflective coatings, and necessary transport means can be present, as well.

The production line 1 of the present invention can be applied to a large variety of different molds consisting of a front molding shell 11, a back molding shell 12 and a sealing means 13, e. g. to molds with the front and the back molding shells 11 and 12 having identical dimensions. However, a lot of complicated and therefore critical and expensive positioning elements can be avoided, if the production line 1 is designed for a preferred mold composed of a front molding shell 11 that is larger in its lateral dimension or diameter than the back molding shell 12 and a sealing means 13 with an aperture 14 (preferably a cylindrical aperture as shown in Figure 2A to 2D) and a contact area 15 for the front

molding shell 11 radially extending from said aperture 14, which sealing means 13 is suitable to receive in a sealing manner the back molding shell 12 within said aperture 14 and the front molding shell 11 on said contact area 15.

For assembling such a preferred mold (or a tight molding cavity 16, respectively) the molding apparatus 2 comprises a radially-acting-means 17 for sealing said sealing means 13 to the back molding shell 12 and an axially-acting-means 18 for axially pressing said front molding shell 11 to said contact area 15 (see Figures 2A to 2D). If both molding shells 11, 12 have identical diameter, or if the sealing means 13 is suitably shaped, both molding shells 11, 12 can be placed in the sealing means 13 such that usually one radially-acting-means 17 is sufficient, but more complex positioning means are needed for precisely positioning both molding shells 11, 12 according to specific lens prescriptions. It shall be emphasized that the production line 1 is suitable to produce lenses 10 of arbitrary prescriptions, including any optical corrections such as toric, multifocal, progressive, prism, decentering or other corrections.

If the sealing means 13 comprises a gasket 13, said radially-acting-means 17 can be a means for radially enlarging and/or reducing the diameter of the aperture 14 such that in released and/or pressed position said gasket 13 provides a sealing to at least the back molding shell 12. Since the radially acting means is simultaneously an aid during the formation of the molding cavity and a sealing (assisting) means, the assembling - as shown in Figure 2A to 2D - can be made at one and the same place, preferably at the lens forming place as indicated in Figure 1.

In order to fill the molding cavity 16 with lens forming material, usually polymeric material (i.e. polymer forming material such as monomers and/or oligomers and/or pre-polymers), a filling opening (not

shown) in the molding cavity 16 surrounding part must be present. Although such opening might be present in one or both of the molding shells 11, 12, in view of positioning and connecting/disconnecting necessity in such embodiment, a filling opening in the sealing means 13 is preferred.

While both molding shells 11, 12 needed to assemble the molding cavity 16 can be provided by one and the same molding-shell-transporting-means 4, also two separate means 4 can be provided, a back-molding-shell-transporting-means 4 for fetching a back molding shell 12 and for positioning said back molding shell 12 in said aperture 14 and a front-molding-shell-transporting-means 4 for fetching a front molding shell 11 and for positioning said front molding shell 11 on said contact area 15. The presence of two such means 4 is in particular suitable, if the front molding shells 11 and the back molding shells 12 are stored in separate molding-shell-storages 3 or in spaced parts of one and the same molding-shell-storage 3. Dependent of the type of molding-shell-storage 3 and the distance between the molding-shell storage 3 and the molding apparatus 2, at least one of said molding-shell-transporting-means 4 comprises a molding-shell-fetching means (indicated by arrows reaching into the molding-shell storage 3) for fetching a molding shell 11, 12 from the molding-shell-storage 3 and putting it on a molding-shell-conveying-means 4 designed to transport said molding shell 11, 12 to the molding apparatus 2, where it is accessible to a molding-shell-positioning means (indicated by arrows reaching into the molding apparatus 2) designed to fetch said molding shell 11, 12 and to position said molding shell 11, 12 in or on said sealing means 13. Note that the molding-shell-transporting-means 4 are designed to deliver molding shells 11, 12 from a sufficiently large molding-shell-storage 3 to provide various molding shells 11, 12 for automatized production of a large variety of lens pre-

scriptions. Said molding-shell-transporting-means 4 can be in one or several part form, optionally interrupted by a conditioning device (not shown, see also below).

Examples for molding-shell-fetching-means are robot arms, and for molding-shell-conveying-means a conveyor belt, preferably with trays 61, 62, molding shell revolvers, etc.

It is also possible to use movable molding-shell-storages 3, or molding-shell-storages 3 comprising movable storage units. Such molding-shell-storages 3 can not only bring the desired molding shell 11, 12 in a desired position with regard to the molding-shell-fetching-means, but they can even be designed and positioned such that they act as molding-shell-conveying-means 4 making any fetching and transporting means other than the molding-shell-positioning-means dispensable.

Examples for molding-shell-storages 3 are storage cassettes, comprising the molding shells 11, 12 in an upright position, or, preferably, roundabouts or revolvers with storage capacity comprising several places for different molding shells 11, 12, each of said places being suitable to store one or several molding shells 11, 12 of the same kind.

If different molding-shell-storages 3 are used for front molding shells 11 and back molding shells 12, they can independently of each other be movable or not movable, connected with one multifunctional molding-shell-transporting-means 4, or with a several parts comprising molding-shell-transporting-means 4, i. e. a molding-shell-transporting-means 4 comprising a molding-shell-fetching-means, a molding-shell-conveying-means and a molding-shell-positioning-means, whereby two of said means may be integrated in one partial means.

Dependent on the storage time and the environment, it may be advantageous to pre-condition the optical mold surface of at least part of the molds e.g. by spraying conditioning solution onto said surface and dry-

ing said surface afterwards. Such drying can e.g. be performed by fast spinning or by a gas (air) stream. Alternatively, the pre-conditioning can be performed by an ionized gas (air) stream.

The pre-conditioning in general is performed shortly before the filling of the molding cavity 16 with lens forming material to ensure that the optical surfaces of the molding shells 11, 12 are in the desired condition.

The conditioning devices (not shown) can be positioned anywhere between the molding shell storage 3 and the assembly and filling station of molding apparatus 2. In specific cases, the conditioning device can even be integrated into the molding apparatus 2 such that the already assembled molding cavity 16 can be conditioned.

Dependent on the place and embodiment of the conditioning device, more than one molding-shell-transporting-means might be needed.

If the production line 1 is designed for the preferred embodiment of a mold as described above, positioning can be made by simply introducing a stop for positioning the front molding shell 11, said stop defining an axial position and/or a basic lateral or radial position of the front molding shell 11 with respect to the sealing means 13. Such stop can e. g. be at least one fixedly mounted metal part fixing the axial position of the front molding shell 11 independent of the axial force applied. Such metal part can also comprise one or more noses or similarly acting parts preventing the lateral displacement of the front molding shell 11 in the nose-blocked direction. In particular, if the front molding shell 11 is not of perfectly symmetrical shape, a lateral stop may also serve as stop to indicate a basic position with regard to rotation about the axis 9 through the center of the aperture 14, i. e. perpendicular to the contact area 15 of the sealing means 13.

Whether or not a basic rotational position can be fixed by a stop, the front- and/or back-molding-shell-transporting-means 4 can in any case be designed such as to allow rotation of the front molding shell 11 and/or back molding shell 12, respectively, about said axis 9, preferably said axis 9 through the center of the aperture 14 or sealing means 13, respectively.

Said front-molding-shell-transporting-means 4 can also be designed such that a transverse or radial movement of the front molding shell 11 for decentering the front molding shell 11 is possible. In a further embodiment, said front-molding-shell-transporting-means 4 is able to rotate and to transversely or radially move the front molding shell 11.

The contact area 15 of said sealing means 13 can have several different lateral extensions. It can at least partially laterally surpass the laterally extending abutting part of the front molding shell 11, in particular in basic position. This enables easy decentering without loosing any or a noticeable sealing contact area 15. If only part of said contact area 15 has a lateral extension corresponding to the extension of the molding shell 11, 12, provided that the sealing contact area 15 is sufficiently large, the laterally extending abutting part of the molding shell 11, 12 surpassing said contact area 15 can be brought in contact with one or more stop areas that are equiplanar with the contact area 15. It is also possible to have e. g. a ring-shaped contact area 15 that is smaller than the e. g. also ring-shaped laterally extending abutting part of the front molding shell 11. In this embodiment, an axially acting stop might also be ring shaped. Such embodiments of the sealing means 13, in particular a gasket 13, are not only usable in a production line 1 but are suitable for any above described mold with abutting front molding shell 11.

The production line 1 of the present invention preferably also comprises an assembly-transporting

means 6 and a demolding apparatus 7, said assembly-transporting-means 6 being for fetching an assembly 70 consisting of a front molding shell 11, a back molding shell 12 and an at least partially cured lens 10 between said molding shells 11, 12, for transporting said assembly 70 to said demolding apparatus 7, and for positioning said assembly 70 or molding shell 11, 12, respectively, in said demolding apparatus 7. If said lens 10 is not fully cured prior to being fetched by the assembly-transporting-means 6, a further curing step may be provided prior to the delivery to the demolding apparatus 7. In a preferred embodiment the molding and demolding apparatuses 2, 7 are highly integrated such that after molding the assembly 70 can remain essentially in an unchanged position for applying demolding means of the demolding apparatus 7, in particular for removing the gasket 13 and for applying force, heat and/or airstream to demold the lens 10 from the molding shells 11, 12. In this case assembly-transporting means are not needed.

Although the sealing means 13, in particular a gasket 13, could be moved together with the molding shells 11, 12 and the at least partially cured lens 10 outside the molding apparatus 2, e.g. into a demolding apparatus 7(i.e. that the sealing means 13 is removed outside the molding apparatus 2, e. g. in the demolding apparatus 7), it is preferred that the sealing means 13 is removed immediately in the molding apparatus 2. The molding shells with the at least partially cured lens therebetween thus are preferably separated within the molding apparatus 2 from the sealing means 13 and then - provided that the demolding device is not integrated within the molding apparatus 2 - moved outside the molding apparatus 2 - possibly after a final curing step, e.g. a thermal curing step - into the demolding apparatus 7 by the assembly-transporting-means 6. In this embodiment, the sealing means 13 remains in the molding apparatus 2 in the desired position and preferably connected to

the liquid lens forming material providing unit for subsequent molding procedures. Thus, an assembly 70 referred to above usually consists in a front molding shell 11, a back molding shell 12 and a lens 10 therebetween.

While US 6,103,148 discloses to assemble sealing means 13 and molding shells 11 and 12 in an assembling apparatus locally separated from the filling module which is yet again also locally separated from the curing station, the preferred molding apparatus used according to the present invention allows to perform the following steps at the same location, namely (i) to form the molding cavity 16, (ii) to fill the lens forming material, into the molding cavity 16 and (iii) to cure the such formed lens 10 by irradiation. The performance of these three steps at the same location allows to reduce floor space and transportation time. Preferably also the removing of said sealing means 13 is done at the same location, such that the assembling and the filling of the molding cavity 16, the curing of the filled molding cavity 16, and the transport of an assembly 70 consisting of a cured lens 10 and said two molding shells 11, 12 outside of the molding apparatus 2 is done without delocalization of the sealing means 13.

If the lens 10 is only partially photo cured as long as the molding cavity 16 is still intact (i.e. the sealing means, especially the gasket 13 is not yet removed) at the same place a thermal radiation curing by e.g. an infrared lamp might be done, or, preferably the gasket 13 is removed and the remaining assembly 70 is thermally and/or photo post-cured outside the molding apparatus, dependent on the initiator(s) present in the lens forming material. Said initiator(s) can be at least one photo initiator and/or at least one thermal initiator.

The assembly-transporting-means 6 may be a multifunctional means 6 or it can comprise an assembly-fetching-means (indicated by arrows reaching into the

molding apparatus 2), an assembly-conveying-means 6 and an assembly-positioning-means (indicated by an arrow reaching into the demolding apparatus 7), said assembly-fetching-means being able to fetch such assembly 70 in the molding apparatus 2 and to deliver it to the assembly-conveyer-means 6 that brings it to the demolding apparatus 7, and said assembly-positioning means being designed for positioning the assembly 70 in a demolding means. If the spatial arrangement allows it, two of said assembly-manipulating means can be combined in a partial means of the assembly-transporting means 6.

In a preferred disassembling or demolding apparatus 7 (Figure 3) said demolding means comprises at least one lens-force-applying-means 71 for applying force to the lens 10, in particular close to the interface lens 10/front molding shell 11, and at least one molding-shell-force-applying-means 72, 73 for application of force to at least one molding shell 11, 12, in particular the front molding shell 11. Application of force to the front molding shell 11 and the lens 10 close to the interface front molding shell 11/lens 10 is preferred in view of easy positioning. In the case of a larger front molding shell 11, the laterally extending abutting part of said front molding shell 11 functions as an unambiguous positioning element or positioning mark.

In particular, for disassembling the preferred assembly 70 with larger front molding shell 11, the demolding apparatus 7, or rather the demolding means comprises a lens holder 74 for positioning the assembly 70 and holding the lens 10. Such a lens holder 74 is preferably designed to be able to apply a lens holding force to the lens 10, preferably by means of several movable legs 741, e. g. four symmetrically positioned legs 741. Said legs 741 define an aperture 14 that in charging position, i. e. with no force applied, define an aperture 14 larger than the back molding shell 12 and the lens 10 but smaller than the front molding shell 11 such that the

assembly 70 is positioned thereon with the front molding shell 11 extending to one side of said lens holder 74 and the lens 10 and back molding shell 12 extending to the other side. As soon as the assembly 70 is positioned, pressure force can be applied to the lens 10.

Preferably the lens-force-applying-means 71 and the molding-shell-force-applying-means 72, 73 are such that force is applied to essentially opposite, preferably opposite, sides of the lens 10 and molding shells 11, 12.

Good demolding results are achieved if the force applied to the lens 10 and the force applied to one of the molding shells 11, 12, in particular the front molding shell 11, are parallel forces that act into the same direction. For simultaneous demolding of both molding shells 11, 12, it is preferred that the demolding device comprises at least one molding-shell-force-applying-means 72 acting on the front molding shell 11 and at least one molding-shell-force-applying-means 73 acting on the back molding shell 12, said means preferably being placed such that the force provided to the front molding shell 11 is perpendicular to the force provided to the back molding shell 12.

The force to the lens 10 is preferably applied to the lens 10 by a lens-force-applying-means 71 that has at least one lens-contacting-area 75 of at least 15 mm^2, preferably 15 mm^2 to 30 mm^2, most preferred about 25 mm^2. Preferably the lens-contacting-area 75 has a thickness t smaller than the thinnest lens 10 to be demolded, usually $t \leq 2$ mm, preferably 1 mm $\leq t \leq$ 2 mm, more preferably t=1.5 mm, and/or a circumferential width W of at least 10 mm, preferably 10 mm $\leq W \leq$ 20 mm, more preferred W=16.5 mm.

In another preferred embodiment of the lens-force-applying-means 71 (Figures 3 to 5) the lens-contacting-area 75 is on a finger or protrusion with an overhang or projecting length 76 of 1 mm $\leq l \leq$ 2 mm,

preferably about l=1.5 mm. The overhang 76 is the part of the finger that exceeds the difference in the lateral extension or radius of the front molding shell 11 and the lens 10. In particular, by choosing a length l of the overhang 76 the ratio of a first force applied by the lens-force-applying-means 71 to the lens 10 and a second force applied by the molding-shell-force-applying-means 72 to the at least one molding shell 11, 12, in particular the front molding shell 11, can be chosen according to a predetermined value. Thus the two force-applying-means 71, 72 are combined such that said lens-force-applying-means 71 or its overhang 76, respectively, slightly penetrates the lens 10 upon force application. Both force-applying-means 71, 72 can also have a more independent coupling via a spring loading 711 for the lens-force-applying-means 71 or the overhang 76, respectively.

The force applied to the front molding shell 11 shall be chosen in the range of 100 kg to 400 kg, preferably about 200 kg, and the force applied to the back molding shell 12 is in the range of 100 kg to 200 kg, preferably about 140 kg.

The force that can additionally be applied to the lens 10 by the lens holder 74 is in the range of 10 kg to 20 kg, preferably about 15 kg, in particular if said lens holder 74 is also used as passive force applying means that effects application of a reactive force to opposing sides of the lens 10.

The application of active force to one side of one or both molding shells 11, 12 is also possible. In this case the demolding device 7 comprises a holder 77 for fixing the opposite side of the front molding shell 11 and/or a holder 78 for fixing the opposite side of the second or back molding shell 12.

Dependent on the lens forming material and the lens forming method used, the lens characteristics may be improved by an optional annealing step that is

preferably performed after the demolding step and prior to further lens treatments.

The production line 1 of the present invention can also comprises at least one surface treatment such as a coloration, application of a scratch resistant coating, etc.

Independent of a further treatment, the production line 1 can comprise at least one lens-transporting-means for fetching the lens 10 from the demolding apparatus 7 and transporting it to the next step in the production line 1, such as surface treatment, characterization by engraving a mark, etc., or a lens storage or a lens packaging unit.

The production line 1 of the present invention can also comprise a used-molding-shell-transporting means (indicated on bottom of Figure 1) for transporting the used molding shells 11, 12 from the demolding apparatus 7 to a molding-shell-washing-means 8, a molding shell-washing means 8 for cleaning the used molding shells 11, 12, and a cleaned-molding-shell-transporting-means (indicated in Figure 1 to the left of the operator) for transporting the molding shells 11, 12 back to the molding-shell-storage 3 for storage and further use.

It has proven favorable if the molding shells 11, 12 are placed in a molding-shell-protection-unit or tray or container 61 or 62 (Figures 6a and 6b), said molding-shell-protection-unit 61, 62 protecting said molding shells 11, 12 during storage in the molding-shell-storage 3 and/or during transport in the production line 1, in particular in the molding-shell-transporting-means 4 and/or in the cleaned-molding-shell-transporting-means and/or in the used-molding-shell-transporting means.

Preferably the front molding shell 11 is placed in a first tray 61 (Figure 6a) and the back molding shell 12 in a second tray 62 directly after the washing 8 to avoid any pollution or mechanical damage, such

as scratches, of the molding shells 11, 12 and, in particular, of their active surfaces, i. e. the lens touching or lens forming surfaces. The trays 61 and 62 can also facilitate the automatized handling of the molding shells 11, 12. For this purpose they are provided with at least one recess 611, 621 for giving access to a robot positioning tool (not shown) for placing and fetching the molding shells 11, 12 on and from the trays 61, 62. Furthermore a lower rim or edge 612 or 622 is provided for abutting the shells 11, 12 outside their optical surfaces and in a height position such that the optical surfaces cannot touch the bottom 613, 623 of the trays 61, 62. Clamps 614, 624 are provided for withholding the shells 11, 12 in their position on or in the trays 61, 62, in particular during transportation. Note that the tray 62 for smaller back molding shells 12 is smaller in diameter and comprises additional noses 625 for holding the back molding shells 12 in position.

It is also preferred that the assembly 70 is as well handled and transported in an assembly-protection-unit 61, 62, in particular in the assembly-transporting means 6. The assembly-protection-unit 61, 62 can be identical to the tray 61 for the front molding shells 11, if the assembly 70 is positioned with the front molding shells 11 facing the tray bottom 613. Although pollution is not so critical for the assembly 70, protection against mechanical damage and precise positioning, e. g. on the conveyor belt 4 or 6, are desirable and help in facilitating and automatizing the handling of assemblies 70 in the production line 1.

An advantage of the above described production line 1 is that from one to preferably all steps can be controlled by said operating unit 5 for automatization.

Said operating unit 5 comprises one or more sub-units selected from the following group

- storage-control unit for addressing and providing the desired molding shells 11, 12,
- molding-control-unit for assembling the front molding shell 11, the back molding shell 12 and the sealing means 13 such that together they form the molding cavity 16,
- molding-operating unit 5 for steering the filling of the molding cavity 16 with lens forming material and for curing the lens forming material in the molding cavity 16 by heat or irradiation,
- assembly-operating-unit for transporting the assembly 70 to the demolding apparatus 7 and for bringing said assembly 70 in demolding position,
- demolding-operating-unit for steering the demolding,
- molding-shell-operating-units for transporting the demolded molding shells 11, 12 to a washing unit 8 and/or a molding-shell storage 3, and
- lens-operating-unit for transporting the lens 10 to a further treatment and/or a lens storage and/or a lens packaging unit (not shown).

The molding-operating-unit preferably also steers or controls the curing of the lens forming material in the molding cavity 16 by heat and/or irradiation according to a specific spatio-temporal energy distribution program.

The molding-operating-unit preferably also steers the removal of the sealing means 13 within the molding apparatus 2.

Either the molding-operating-unit or the assembly-operating-unit can be used to steer or control the placing of the assembly 70 in the assembly-protecting-unit 61.

The molding-shell-operating-unit can also be such that it steers or controls the placing of the molding shells 11, 12 in their respective molding-shell-protecting-units 61 or 62.

All or parts of the operating unit 5 or sub-units, respectively, can be implemented by hardware and/or software. All steering or control operations can be provided with control and/or sensor means to provide input to a suitable feedback circuit for automatic production line control and production error recognition and production error handling and correction.

In a preferred embodiment, the molding apparatus 2 can comprise any curing device for faster curing of the polymeric material, such as e. g. a heat or irradiation curing device, in particular a UV-curing device. Said heat or irradiation curing device preferably comprises a heat or irradiation source, in particular a UV lamp, and preferably means for controlling a spatio-temporal distribution of the irradiation intensity, such as an openable iris, spatially inhomogeneous absorption filters and/or spatial light modulators.

Figure 7 shows an embodiment of the molding apparatus 2 and of its operation for making an ophthalmic lens 10 with improved shrinkage compensation and increased production quality and speed. The front and back molding shells 11, 12 together with the gasket 13 provide the molding cavity 16 with an opening 201 for filling in liquid polymerizable synthetic material 202. The lateral extensions of the molding surfaces 211, 212 define transverse directions 214 and their spatial separation an axial direction 213 of the mold 16 or ophthalmic lens 10, respectively. A radiation source 215, such as a UV-light source 215, emits an irradiation or light that may be expanded by an appropriate optics 216 to form an irradiation or illumination intensity 217. A transversely and temporally modulated irradiation intensity 217' or $I_0(x, y, t)$ is obtained by transversely modulating or gradually deblocking the originally formed irradiation intensity 217 by means of a shutter or iris diaphragm 218 that is openable along a direction 218a. Beam shaping optics 220, such as at least one absorption filter 220 and/or at

least one spatial light modulator 220, may be used to complement or replace the iris diaphragm 218. The molding operation of the molding apparatus 2 is managed by a molding-operating-unit 219. In particular, if a homogeneous intensity distribution $I_0(x, y)$=constant is supplied, the speed of opening the iris 218 shall be retarded with increasing diameter, when making a concave lens 10, and shall be accelerated with increasing diameter, when making a convex lens 10. Furthermore, an initial opening in the otherwise closed iris 218 may lead to a small cylinder volume hardening quicker through the mold thickness, because hardening is begun already before the iris opening 218a is started. In the embodiment of Figure 7 the back molding shell 12, through which irradiation 217' is entering the mold 16, is equipped with an additional absorption filter 220 or spatial light modulator 220 to further modulate the intensity 217' transversely. A spatial light modulator 220 is advantageous in that it can be addressed and controlled dynamically by the molding-operating-unit 219 to provide an arbitrary, time-variable transverse intensity distribution 217'. It is thus very suitable to implement specific spatio-temporal energy distribution programs that are adapted to the lens 10 to be made, in particular that are adapted to provide optimal shrinkage compensation for the lens 10 to be made. In particular, an apodized or concave intensity distribution 217' or $I_0(x, y, t)$ is provided by the absorption filter or spatial light modulator 220. The absorption filter 220 can be implemented by a coating 220 on an outer surface of the back molding shell 12. Spatial light modulators 220 with high image quality, fast response times and suitability for use in transmission are known to the skilled person and are commercially available. For bilateral irradiation through both the front and back molding shell 11 and 12, both molding shells 11 and 12 may have absorption filters 220 and/or spatial light modulators 220. When unilateral illumination is provided the roles

of the back and front molding shells 11, 12 may in principle be exchanged.

The modulated irradiation intensity 217' impinges on the back molding shell 12 that is transparent to the irradiation 217', enters the molding cavity 16 through the first molding surface 212 and induces a polymerization process in an illuminated portion or volume 221 of the synthetic material 202. After a while a solidification front 222 of the illuminated volume 221 approaches the second molding surface 211 and forms a gap. According to a preferred embodiment the impinging illumination intensity 217' is modulated in the transverse directions 214 and in time such that a liquid layer 223 is formed between the solidification front 222 and the second molding surface 211 with a thickness that is increasing as a function of at least one transverse direction 214 of solidification. In other words, the liquid layer thickness must be an increasing function in a transverse direction 214, into which the solidification is progressing. When the solidification is started in a central portion 221, as is usually but not necessarily the case, the increase of the liquid layer thickness must occur in a transverse direction 214 oriented outwards or towards the periphery of the mold 16. This is achieved by apropriately controlling the curing speeds in the axial and transverse directions 213, 214. The curing speed in axial direction 213 may be defined as the speed of spatial progression of a gelation front 222 into the mold 16 in the axial direction 213. Similarly a transverse curing speed describes the temporal evolution of progression of the gelation front 22 in the mold 16 in a transverse direction 214. The invention thus provides a channel, namely the liquid layer 223, with a favourable geometry for giving free access for a mainly transverse inflow 224 of liquid polymerizable synthetic material 202 that compensates an axial shrinkage of the solidifying synthetic material 202 in the hardening volume 221.

It shall be understood that the term solidification refers to any partial polymerization, such as gelation, or complete polymerization of the synthetic material 202, that is associated with an immobilization of liquid material monomeres 202. A gel point may correspond to a 15% - 30% partial polymerization. The shrinkage starts during gelation and continues until the polymerization is completed. Typically total shrinkage amounts to 5% - 15% of the starting volume of liquid material 202. By the invention the effect of shrinkage in the axial direction 213 can thus be largely reduced or even eliminated without resorting to time-consuming stepwise polymerization schemes. It can be sufficient to control the formation of the liquid layer 223 only to the extent that an optically usable part of the optical element 10 is solidified. Therefore, liquid material 202 needed for axial and transverse shrinkage compensation may be drawn from peripheral portions outside the optically usable part. Alternatively, fresh material 202 can be supplied during polymerization, possibly under slight pressure, to refill the mold 16 and supplement for the shrunken volume.

Furthermore, the first and/or second molding surface 212, 211 of the mold 16 may be passively or actively movable in the axial direction 213 during polymerization. Preferably the molding surface 212, 211 through which the irradiation is entering the mold 16, shall be the movable one. The movement may be passive, e. g. by providing an annular sealing means 13 of the mold 16 with sufficient elasticity to allow at least one molding shell 11, 12 to move in the axial direction 214, or it may be active, e. g. by an actuator steered by the molding-operating-unit 219. As well, at least one movable mounting (not shown) for at least one molding shell 11, 12 of the mold 16 may be provided to achieve passive or active movability of the first and/or second molding surface 212, 211 in the axial direction 213.

While there are shown and described presently preferred embodiments of the invention, it is to be distinctly understood that the invention is not limited thereto but may be otherwise variously embodied and practised within the scope of the following claims.

Claims

1. A production line (1) for the production of optical, in particular ophthalmic lenses (10), comprising a molding apparatus (2), at least one molding-shell-storage (3), at least one molding-shell-transporting-means (4), and at least one operating unit (5), wherein

- said molding apparatus (2) comprises a sealing means (13) defining an aperture (14) around an axis (9), in particular an essentially circular aperture, a liquid lens forming material conveying unit to fill a molding cavity (16) formed by a front molding shell (11) and a back molding shell (12) and the sealing means (13),

- said at least one molding-shell-storage (3) comprises the molding shells (11, 12) in a manner suitable to allow easy access to a specific molding shell (11, 12) by the molding-shell-transporting-means (4),

- said at least one molding-shell-transporting-means (4) being able to fetch molding shells (11, 12) from the molding-shell-storage (3) and to position said molding shell (11, 12) in or on said sealing means (13),

- said at least one operating unit (5) being designed such that it guides the molding-shell-transporting-means (4) to fetch and position the back molding shell (12) and/or the front molding shell (11) in or on said sealing means (13), such that together with the sealing means (13) they form a molding cavity (16), and wherein

- said molding apparatus (2) is constructed such that it allows to perform the following steps at the same location, namely to (i) assembly said gasket (13) and said front molding shell (11) and said back molding shell (12) to form said molding cavity (16), and (ii) to fill said molding cavity (16), and (iii) to at least partially cure said filled molding cavity (16), and (iv) to

remove said sealing means (13), such that the assembling and the filling of the molding cavity (16), the curing of the filled molding cavity (16), and the transport of an assembly (70) consisting of an at least partially cured lens (10) and said two molding shells (11, 12) outside of the molding apparatus (2) is done without delocalization of the sealing means (13).

2. The production line (1) of claim 1, wherein said sealing means (13) is radially extending from said aperture (14) to form a contact area (15) for the front molding shell (11), and wherein said molding apparatus (2) comprises a radially-acting-means (17) for sealing said sealing means (13) to the back molding shell (12) and an axially-acting-means (18) for axially pressing said front molding shell (11) to said contact area (15).

3. The production line (1) of claim 1 or 2, wherein said sealing means (13) comprises a gasket (13), a radially-acting-means (17) for radially enlarging and/or reducing the diameter of said aperture (14) such that in released and/or pressed position said gasket (13) provides a sealing to at least the back molding shell (12).

4. The production line 1 of anyone of the preceding claims wherein the sealing means (13) comprises a filling opening (201) allowing access of the Liquid lens forming material (polymeric material) (202) to the molding cavity (16).

5. The production line (1) of anyone of the preceding claims, that comprises two molding-shell-transporting-means (4), a back-molding-shell-transporting-means (4) for fetching a back molding shell (12) and for positioning said back molding shell (12) in said aperture (14) and a front-molding-shell-transporting-means (4) for fetching a front molding shell (11) and for positioning said front molding shell (11) on said contact area (15).

6. The production line (1) of anyone of the preceding claims, wherein at least one of said molding-shell-transporting-means (4) comprises a molding-shell-fetching means for fetching a molding shell (11, 12) from the molding-shell-storage (3) and putting it on a molding-shell-conveying-means (4) designed to transport said molding shell (11, 12) to the molding apparatus (2), where it is accessible to a molding-shell-positioning means designed to fetch said molding shell (11, 12) and to position said molding shell (11, 12) in or on said sealing means (13).

7. The production line (1) of claim 6 wherein said molding-shell-fetching means is a robot arm and said molding-shell-conveying-means (4) is a conveyor belt, preferably with trays (61, 62), or a molding shell revolver.

8. The production line (1) of anyone of the preceding claims, wherein said at least one molding-shell-storage (3) is a movable storage or comprises movable storage units.

9. The production line (1) of anyone of the preceding claims, wherein said molding-shell-storage (3) is a storage cassette, comprising the molding shells (11, 12) in an upright position, or preferably a roundabout or revolver storage, comprising several places for different molding shells (11, 12), each of said places being suitable to store one or several molding shells (11, 12) of the same kind.

10. The production line (1) of anyone of the preceding claims, comprising two molding-shell-storages (3), one for front molding shells (11) and one for back molding shells (12).

11. The production line (1) of anyone of the preceding claims, wherein the molding apparatus (2) comprises a stop for positioning the front molding shell (11), said stop defining an axial position and/or a basic

radial position of the front molding shell (11) with respect to the sealing means (13).

12. The production line (1) of claim 11, wherein said stop is at least one fixedly mounted metal part fixing the axial position of the front molding shell (11) independent of an axial force applied.

13. The production line (1) of claim 11 or 12, wherein said stop fits with a mark in or on the front molding shell (11).

14. The production line (1) of anyone of the preceding claims wherein the front- and/or back molding-shell-transporting-means (4) is or are designed such as to allow rotation of the front molding shell (11) and/or the back molding shell (11), respectively, about said axis (9), in particular said axis (9) through a center of the sealing means (13).

15. The production line (1) of anyone of the preceding claims, wherein said front-molding-shell-transporting-means (4) is designed such that radial movement of the front molding shell (11) for decentering the front molding shell (11) is possible.

16. The production line (1) of one of claims 2 to 15 wherein the contact area (15) of said sealing means (13) at least partially surpasses a laterally extending abutting part of the front molding shell (11), in particular in a basic position.

17. The production line (1) of one of claims 2 to 15 wherein a laterally extending abutting part of the front molding shell (11) at least partially surpasses the contact area (15).

18. The production line (1) of anyone of the preceding claims, wherein the molding apparatus (2) comprises a heat or irradiation curing device (200), in particular a UV-curing device (200).

19. The production line (1) of claim 18, wherein said heat or irradiation curing device (200) comprises a heat or irradiation source (215), in particular

a UV lamp (215), and control means (218, 220, 219) allowing a spatio-temporal energy distribution control, in particular allowing: a continuous adaptation of an irradiation area in a mold (16) by means of an iris diapragm (218), preferably in combination with an absorption filer (220), and/or a spatial light modulator (220) to control a curing speed in transverse directions (214), and/or an intensity level adaptation of the radiation source (215) by means of a radiation source control and/or a spatial light modulator (220) and/or an absorption filter (220) to control a curing speed in an axial direction (213), and/or a preparation of a gaussian, constant or concave beam profile.

20. The production line (1) of anyone of the preceding claims , wherein the liquid lens forming material comprises at least one photo initiator and possibly also one or more thermal initiators.

21. The production line (1) of anyone of the preceding claims, wherein means for performing a further thermal and/or photo curing step, preferably a thermal curing step are provided at a location other than the molding cavity (16) forming, filling and curing location.

22. The production line (1) of anyone of the preceding claims comprising a demolding apparatus (7), in particular together with an assembly-transporting means (6), for demolding an assembly (70) consisting of a front molding shell (11), a back molding shell (12) and a lens (10) between said molding shells (11, 12), in particular wherein said assembly-transporting-means (6) is designed for fetching said assembly (70), for transporting said assembly (70) to said demolding apparatus (7), and for positioning said assembly (70) in said demolding apparatus (7).

23. The production line (1) of claim 22, wherein said assembly-transporting-means (6) comprises an assembly-fetching-means, an assembly-conveying-means and an assembly-positioning-means, said assembly-fetching-

means being able to fetch such assembly (70) in the molding apparatus (2) and to deliver it to the assembly-conveyer-means that brings it to the demolding apparatus (7), and said assembly-positioning means being designed for positioning the assembly (70) in a demolding means.

24. The production line (1) of claim 22 or 23, wherein a demolding means comprises at least one lens-force-applying-means (71) for applying force to the lens (10), in particular close to an interface lens (10)/front molding shell (11), and at least one molding-shell-force-applying-means (72, 73) for application of force to at least one molding shell (11, 12), in particular to the front molding shell (11).

25. The production line (1) of anyone of claims 22 to 24, wherein said demolding means comprises a lens holder (74) for positioning the assembly (70) and holding the lens (10).

26. The production line (1) of claim 25, wherein said lens holder (74) is suitable to apply lens holding force to the lens (10).

27. The production line (1) of anyone of claims 24 to 26, wherein the lens-force-applying-means (71) and the molding-shell-force-applying-means (72, 73) are such that force is applied to essentially opposite, preferably opposite, sides of the lens (10) and molding shells (11, 12).

28. The production line (1) of anyone of claims 24 to 27 comprising at least one molding-shell-force-applying-means (72) acting on the front molding shell (11) and at least one molding-shell-force-applying-means (73) acting on the back molding shell (12), said means (72, 73) preferably being placed such that the force provided to the front molding shell (11) is perpendicular to the force provided to the back molding shell (12).

29. The production line (1) of anyone of claims 24 to 28, wherein the force applied to the lens

(10) and the force applied to one of the molding shells (11, 12), in particular the front molding shell (11), are parallel forces acting in a same direction.

30. The production line (1) of anyone of claims 24 to 29, wherein the lens-force-applying-means (71) has at least one lens-contacting-area (75) with a thickness of $t \leq 2$ mm, preferably $1 \text{ mm} \leq t \leq 2$ mm, more preferred t=1.5 mm, and a circumferential width W of at least 10 mm, preferably $10 \text{ mm} \leq W \leq 20$ mm, more preferred W=16.5 mm.

31. The production line (1) of claim 30, wherein the lens-force-applying-means (71) comprises the lens-contacting-area (75) on a finger with an overhang (76) of $1 \text{ mm} \leq l \leq 2$ mm, preferably about l=1.5 mm.

32. The production line (1) of anyone of claims 22 to 31, wherein the force applied by the lens-force-applying-means (71) onto the lens (10) is in a predetermined relation to the force applied by the molding-shell-force-applying-means (72) onto the front molding shell (11, 12), in particular wherein the lens-force-applying-means (71) and the molding-shell-force-applying-means (72) are connected by a fixed or spring-loaded (711) mechanical coupling, and in particular wherein the force applied to the front molding shell (11) is in a range of 100 kg to 400 kg, preferably about 200 kg, and the force applied to the back molding shell (12) is in a range of 100 kg to 200 kg, preferably about 140 kg.

33. The production line (1) of anyone of claims 25 to 32, wherein the force applied to the lens (10) by the lens holder (74) is in the range of 10 kg to 20 kg, preferably about 15 kg.

34. The production line (1) of anyone of the preceding claims comprising at least one surface treatment, such as coloration, hard coating and anti-reflective coating or an application of a scratch resistant coating.

35. The production line (1) of anyone of the preceding claims comprising at least one lens-transporting-means for fetching the lens (10) and transporting it to the next step in the production line (1) or to a lens storage or a lens packaging unit.

36. The production line (1) of anyone of the preceding claims comprising a used-molding-shell-transporting means, for transporting the used molding shells (11, 12) from the demolding apparatus (7) to a molding-shell-washing-means (8), a molding-shell-washing means (8) for cleaning the used molding shells (11, 12), and a cleaned-molding-shell-transporting-means for transporting the molding shells (11, 12) back to the molding-shell-storage (3) for storage and further use.

37. The production line (1) of anyone of the preceding claims, wherein the molding shells (11, 12) are placed in a molding-shell-protection-unit (61, 62), said molding-shell-protection-unit (61, 62) protecting said molding shells (11, 12) and allowing improved handling during storage in the molding-shell-storage (3) and/or during transport in the production line (1), in particular in the molding-shell-transporting-means (4) and/or in cleaned-molding-shell-transporting-means and/or in used-molding-shell-transporting means.

38. The production line (1) of claim 37 wherein said molding shell (11, 12) is placed in said molding-shell-protection-unit (61, 62) directly after the washing and for the transport to the molding-shell-storage (3).

39. The production line (1) of anyone of claims 22 to 38, wherein the assembly (70) is placed in a assembly-protection-unit (61, 62) for protection and improved handling, in particular during transport in an assembly-transporting means (6).

40. The production line (1) of anyone of the preceding claims, wherein at least one, preferably all

steps are controlled by said operating unit (5) for automatization.

41. The production line (1) of anyone of the preceding claims wherein said operating unit (5) comprises one or more sub-units selected from the following group

- storage-control unit for addressing and providing the desired molding shells (11, 12),

- molding-control-unit for assembling the front molding shell (11), the back molding shell (12) and the sealing means (13) such that together they form the molding cavity (16),

- molding-operating unit (219) for steering the filling of the molding cavity (16) with lens forming material (202) and for curing the lens forming material (202) in the molding cavity (16) by heat or irradiation,

- assembly-operating-unit for transporting the assembly (70) to the demolding apparatus (7) and for bringing said assembly (70) in a demolding position,

- demolding-operating unit for steering the demolding,

- molding-shell-operating units for transporting the demolded molding shells (11, 12) to a washing means (8) and/or the molding-shell storage (3), and

- lens-operating-unit for transporting the lens (10) to a further treatment and/or a lens storage, and/or a lens packaging unit.

42. The production line (1) of claim 41, wherein the molding-operating unit (219) controls the curing of the lens forming material (202) in the molding cavity (16) by heat or irradiation according to a specific spatio-temporal energy distribution program.

43. The production line (1) of claim 41 or 42, wherein said molding-operating-unit also controls a removal of the sealing means (13) within the molding apparatus (2).

44. The production line (1) of anyone of claims 41 to 43, wherein said molding-operating-unit (219) or said assembly-operating-unit control a placing of the assembly (70) in an assembly-protecting-unit (61, 62).

45. The production line (1) of anyone of claims 41 to 44, wherein said molding-shell-operating-unit controls a placing of the molding shell (11, 12) in a molding-shell-protecting-unit (61, 62).

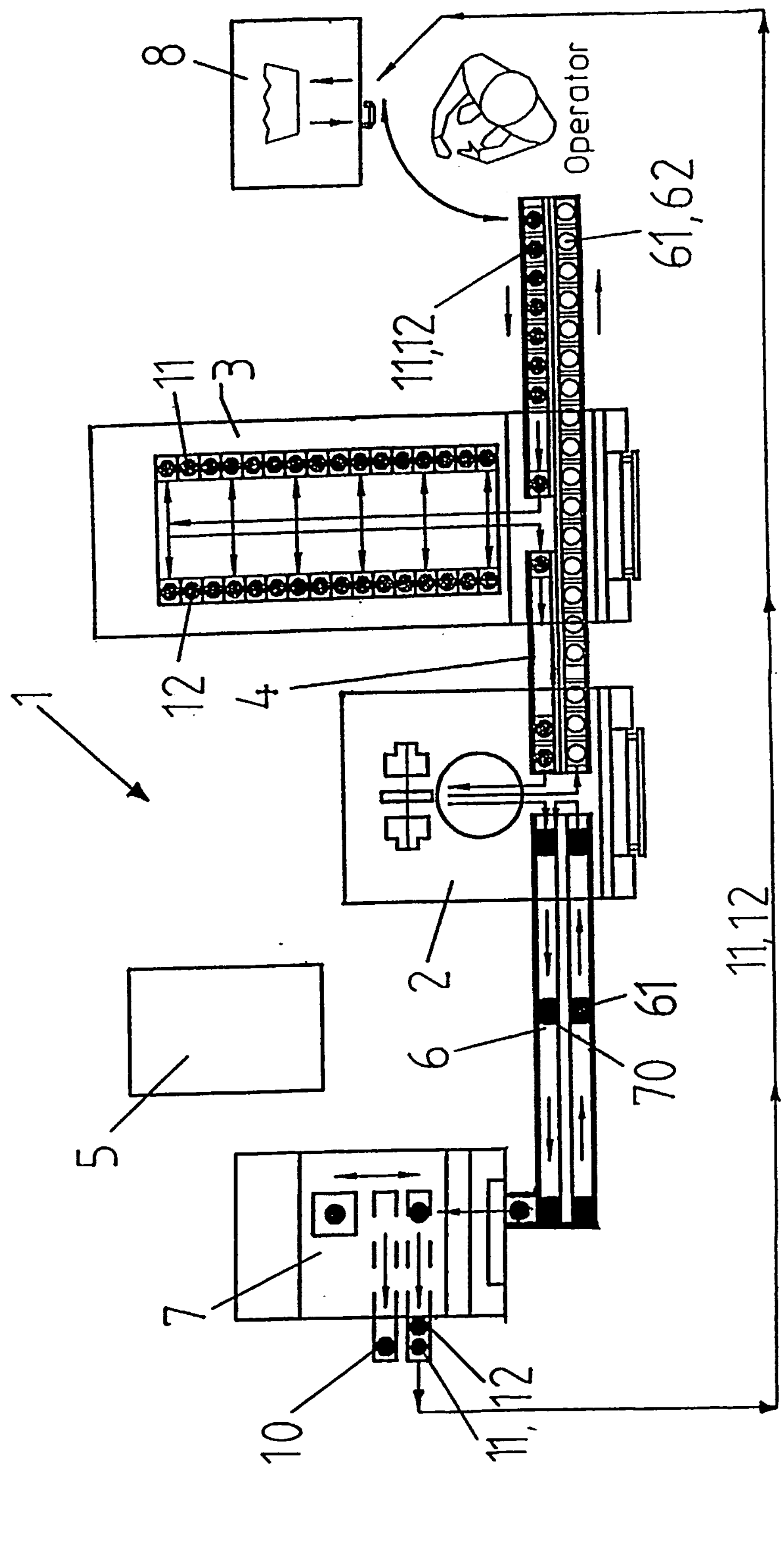

Fig. 1

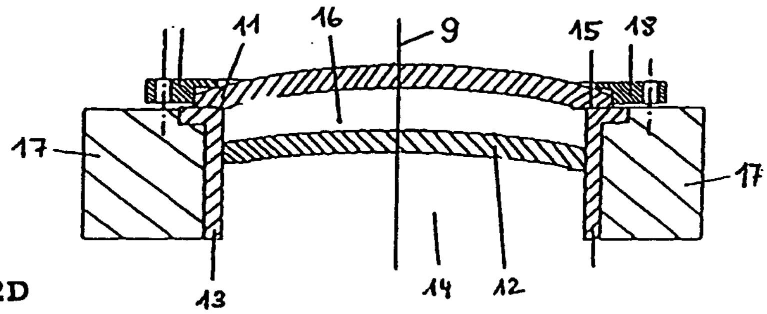

Fig. 2D

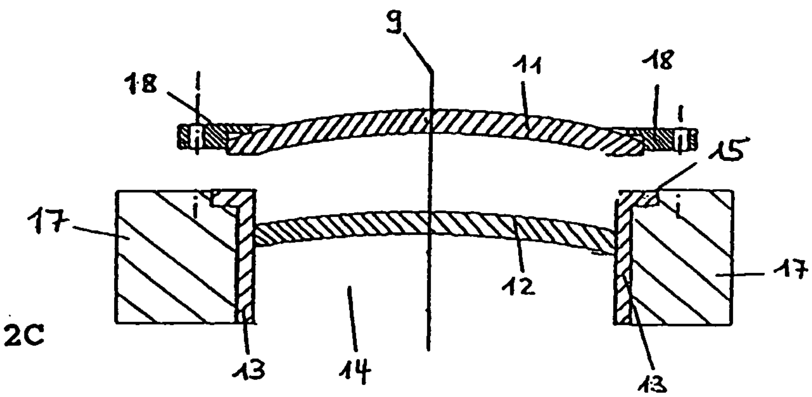

Fig. 2C

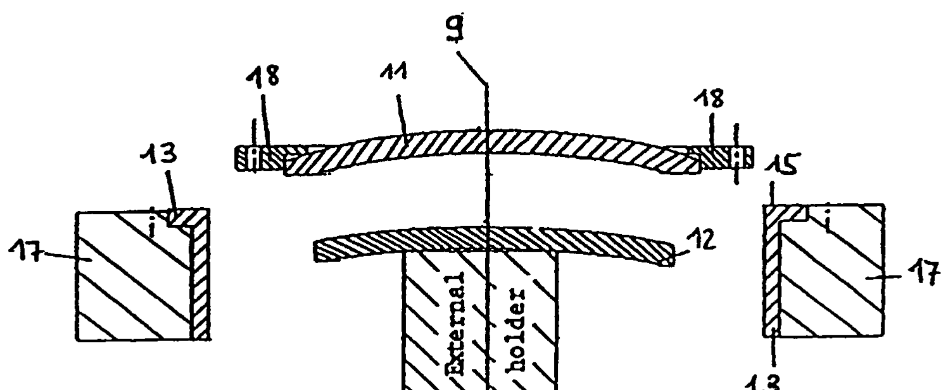

Fig. 2B

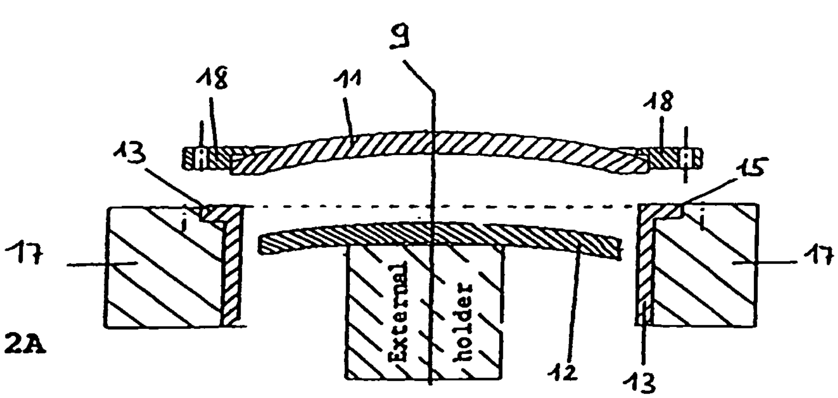

Fig. 2A

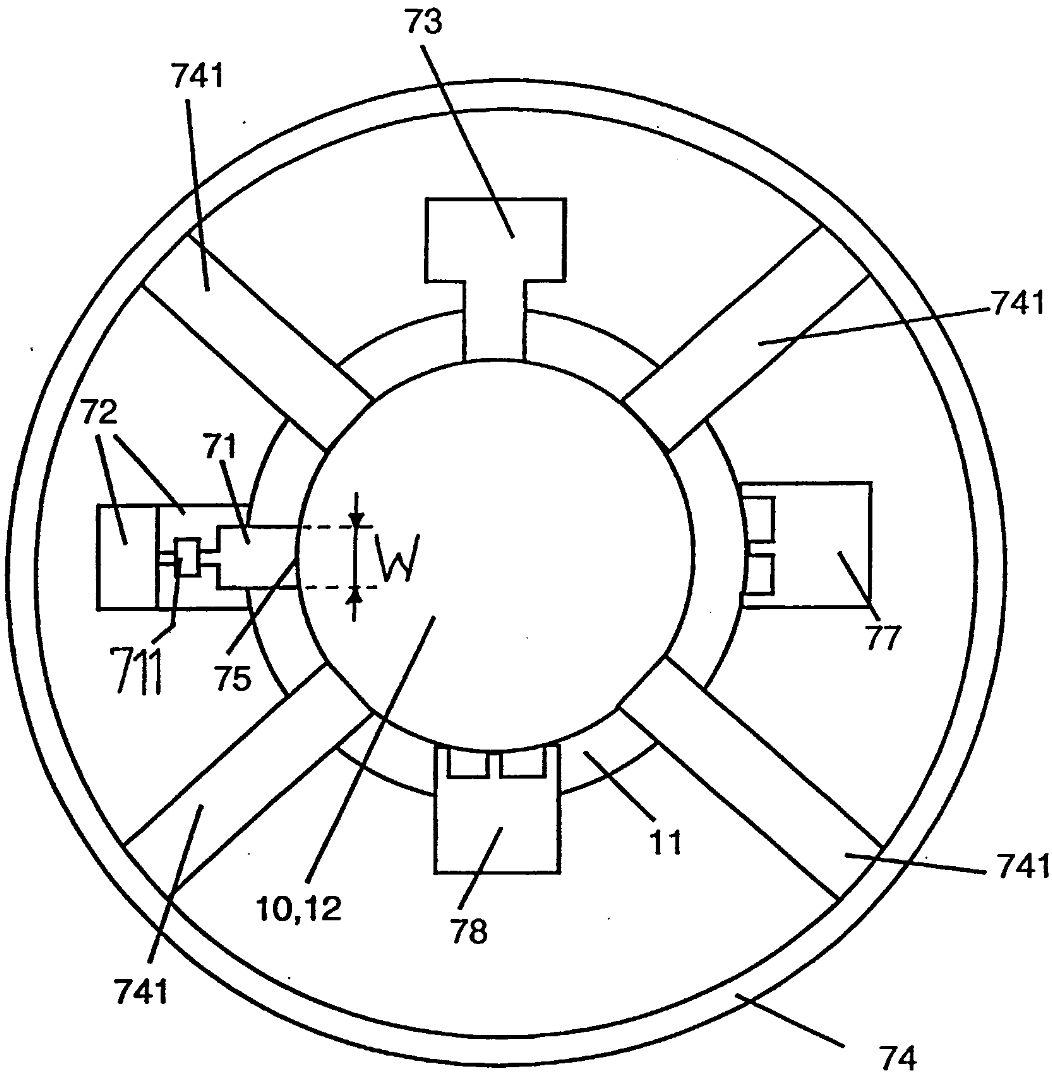

FIG. 3

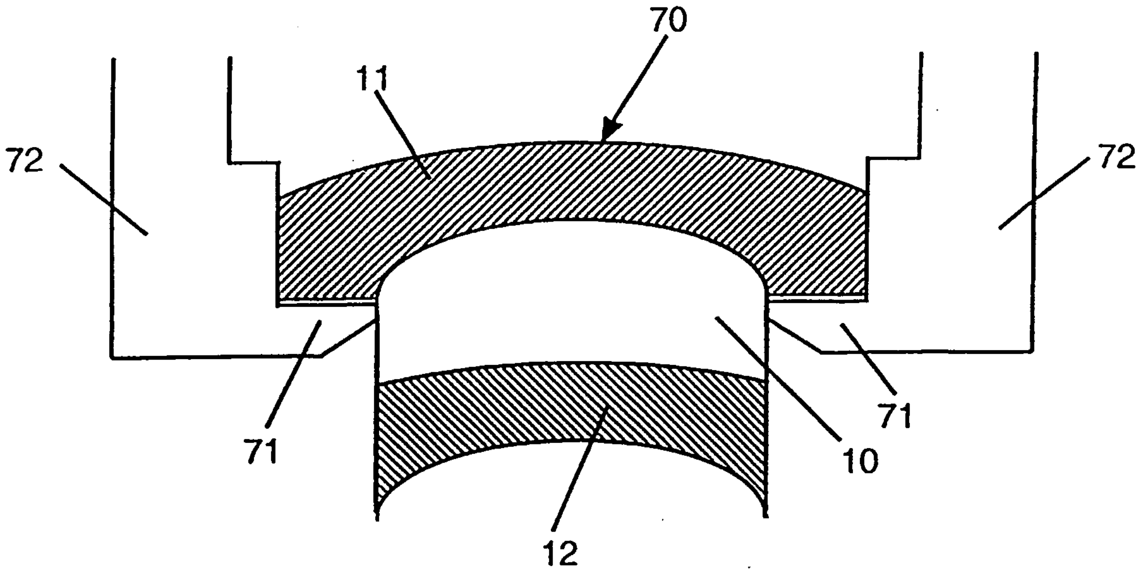

FIG.4

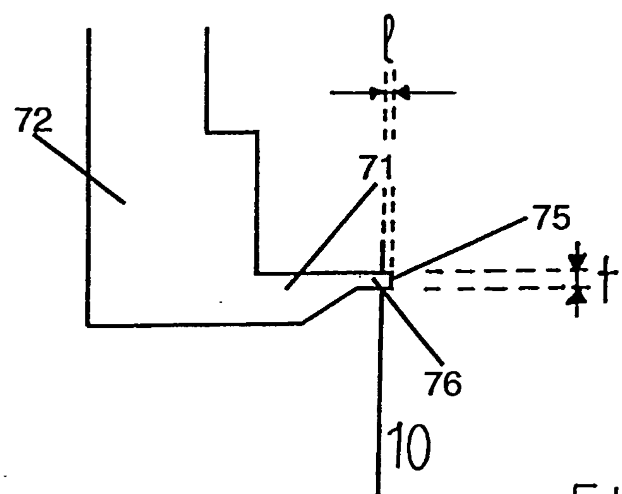

FIG.5

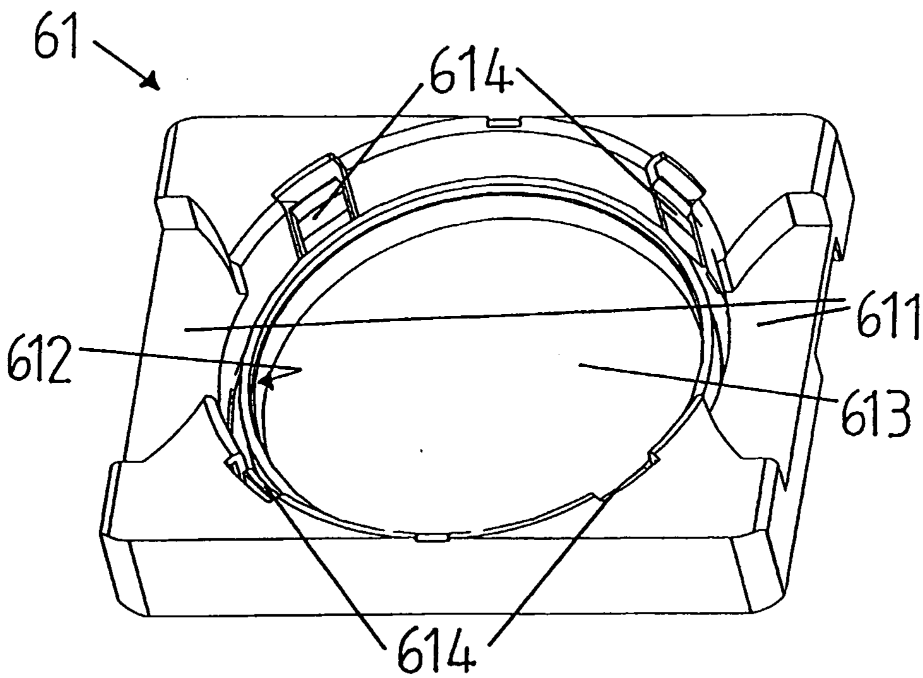

FIG.6a

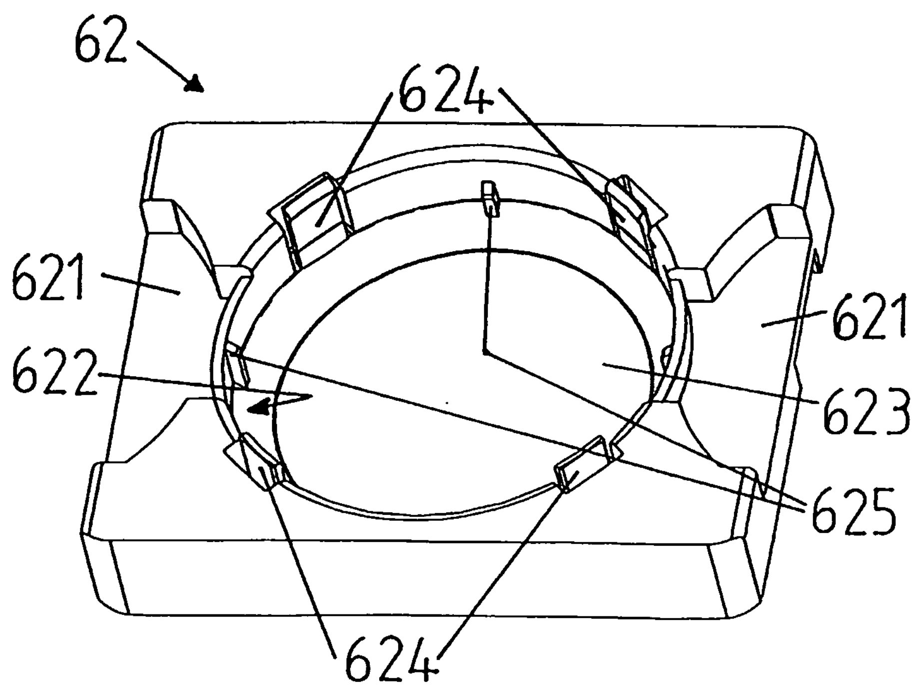

FIG.6b

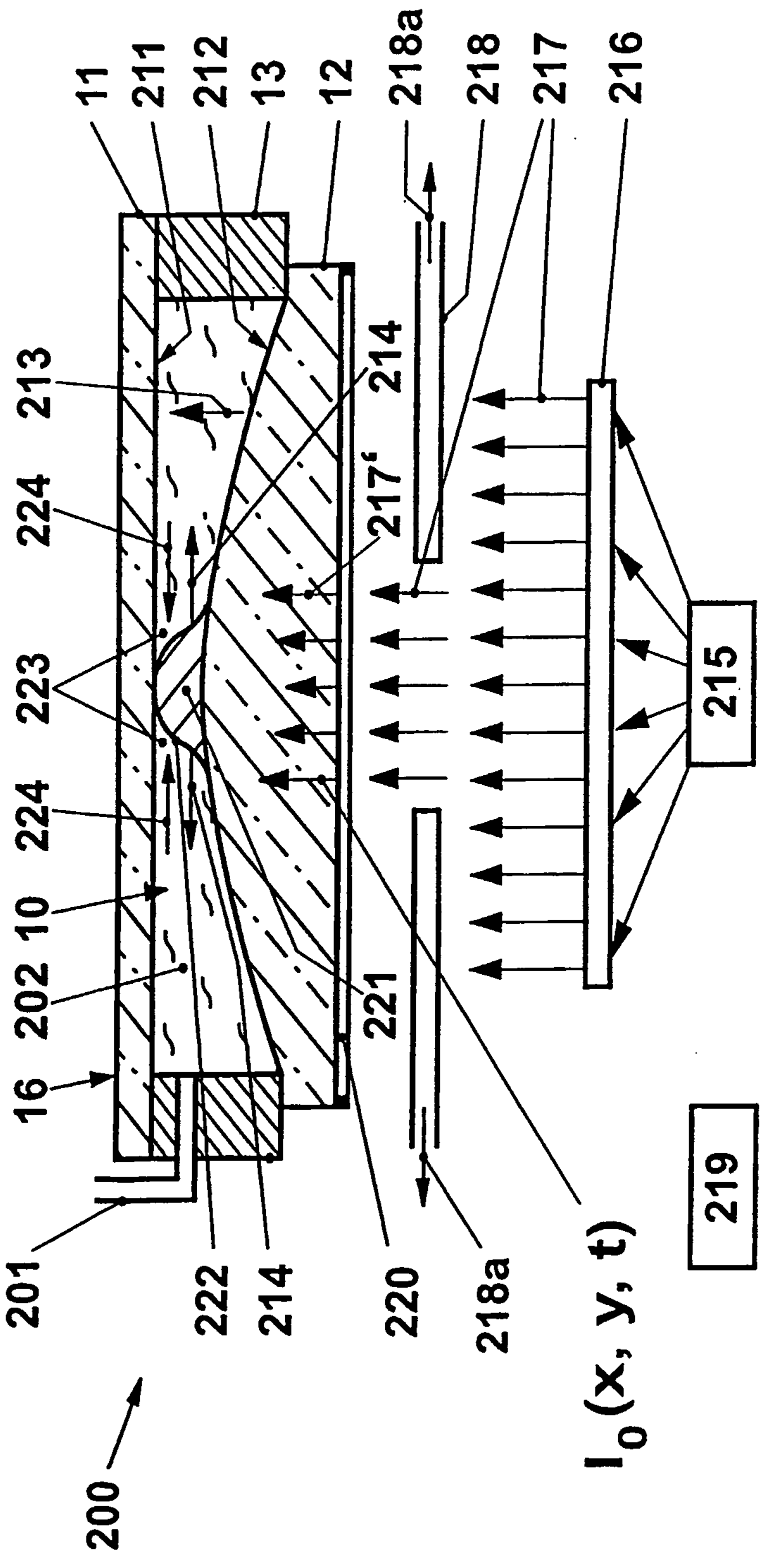
11
211
212
13
12
218a
218
217
216
213
224
223
224
10
202
16
214
217'
215
221
201
222
214
220
218a
$I_0(x, y, t)$
219
200

Fig. 7